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PILOT - SCALE STUDY ON BATAC JIG WASHING OF BRYAN MOUNTAIN COAL - CROWS NEST RESOURCES

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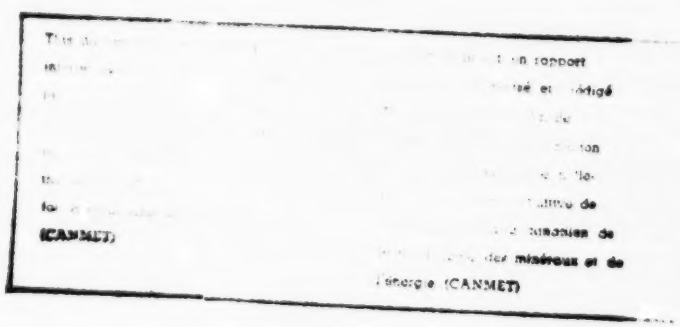

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PILOT-SCALE STUDY ON BATAC JIG WASHING OF BRYAN MOUNTAIN COAL - CROWS NEST RESOURCES

by

M.W. Mikhail*, I.S. Parsons** and O.E. Humeniuk***

ABSTRACT

A 9 tonne sample of thermal coal from Bryan Mountain was submitted by Crows Nest Resources for pilot plant Batac jig evaluation. The objectives of the program were to produce clean coal with a minimum of 26271 kJ/kg heat value and outline a flow sheet to achieve it.

Pilot plant tests included Batac jig circuit with recirculating middlings for the 12.7 x 0.6 mm size fraction and two stage water-only-cyclone for the 0.6 x 0.15 mm fraction. Results obtained gave a recovery of 62.9% by mass at 11.23% (db) ash (equivalent to 27720 kJ/kg) with 90.31% thermal recovery.

Based on coal characteristics and pilot plant testing, a flow sheet is proposed to gravimetrically clean the 200 x 12.7, 12.7 x 0.6 and 0.6 x 0.15 mm in heavy medium bath, Batac jig and water-only-cyclone respectively. Batac jig is recommended over heavy medium cyclone for the 12.7 x 0.6 mm because of the high cutpoint required (about 2.0 dp) and presence of released clays that might cause high magnetite losses. The estimated overall thermal recovery is expected to be approximately 90.7% at 15.47% ash in the clean coal (12.5% ash - a.r.b.).

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ÉTUDE À L'ÉCHELLE PILOTE SUR LE LAVAGE DU CHARBON DE BRYAN MOUNTAIN DANS UN BAC À PISTONNAGE BATAC-- CROWS NEST RESOURCES

par

M.W. Mikhail*, I.S. Parsons** et O.E. Humeniuk***

RÉSUMÉ

Un échantillon de charbon thermique de 9 tonnes de Bryan Mountain a été soumis à Crows Nest Resources à des fins d'évaluation dans un bac à pistonnage Batac à l'échelle pilote. Ce programme avait pour but de produire un charbon épuré ayant un pouvoir calorifique minimal de 26 271 kJ/kg et de présenter un schéma de traitement pour atteindre cet objectif.

Les essais à l'échelle pilote comprenaient un circuit à pistonnage Batac avec des mixtes de recirculation pour la fraction granulométrique de 12,7 x 0,6 mm et un hydrocyclone à deux étapes pour la fraction de 0,6 x 0,15 mm. Les résultats obtenus ont donné un pourcentage massique de récupération de 62,9 % à 11,23 % de cendres par base sèche (équivalant à 27 720 kJ/kg) avec une récupération thermique de 90,31 %.

Selon les propriétés du charbon et les essais à l'échelle pilote, on propose un schéma afin de laver par gravimétrie les fractions de 200 x 12,7, 12,7 x 0,6 et 0,6 x 0,15 mm, respectivement dans un bac de séparation à milieu dense, un bac à pistonnage Batac et un hydrocyclone. On préfère le bac à pistonnage Batac au cyclone à milieu dense pour la fraction de 12,7 x 0,6 mm en raison de la haute densité de coupure nécessaire (environ 2,0) et de la présence d'argiles émises qui pourraient causer d'importantes pertes de magnétite. On prévoit que la récupération thermique globale atteindra environ 90,7 % à 15,47 % de cendres dans le charbon épuré (12,5 % de cendres - tel qu'obtenu).

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INTRODUCTION

A pilot plant scale Batac jig was recently installed at the Coal Research Laboratory (CRL) pilot plant facilities in Edmonton. The Batac jig project is partly financed by several coal companies to evaluate the Batac jig in washing their coals. The project is intended to generate test data and experience on Canadian coals to reduce risks in designing new plants and modifying existing ones.

In Germany, use of the Batac jig in washing both coarse and fine fractions is common in newly designed plants and is gradually replacing the heavy medium bath in existing plants. The common practice is to use the jig to wash the coarse (plus 10 mm) and fine (10 x 0.5 mm) fractions separately. The increased application of the Batac jig both in Germany and other countries is claimed to be due to the following advantages (1):

1. Large tonnages can be treated, simplify plant size and layout and reduce capital cost
2. because of its precise controls, the jig is able to respond quickly to changes either in feed rates or coal characteristics
3. estimated operating cost is 40% less than for the heavy medium systems
4. performance compares favourably with heavy medium systems for cutpoints above 1.55 for coals with limited amount of near density material.

Generally, Canadian coals are not as easy to wash as German coals. The Batac jig offers certain advantages, but an understanding of how it behaves with Canadian coals is not clear. The testing program on different Canadian coals can benefit industry by verifying reported claims and generating data for commercial plant design.

A bulk sample weighing approximately 9 tonnes was collected from four seams in Bryan Mountain area and delivered to CRL. The sample was a composite of four samples defined as Upper Val d'Or (45% by mass), Lower Val d'Or (25%), Lower Val d'Or split (4%) and McPherson (26%)

respectively. This report represents results and discussions of washing tests, evaluates and compares Batac jig performance with other systems and the feasibility of washing Bryan Mountain coal blend to meet required objectives.

COAL CHARACTERISTICS

Based on the analysis in Table 1 and according to the ASTM system of classification, Bryan Mountain composite coal sample can be ranked in the high volatile bituminous category. The analysis given in Table 1 is a split of the bulk sample (approximately 9 tonnes and considered to represent the bulk sample received for washing tests).

SIZE DISTRIBUTION

The sample received was relatively coarse with less than 10.95% by mass finer than 0.6 mm. Tables 2 and 3 show the screen analyses of the raw coal after crushing the raw coal to two top size ranges of 50 mm and 12.7 mm. The analysis indicate a trend common to most Western Canadian coals, i.e. decrease in ash contents with decrease in particle size as relatively lower ash particles tend to be more friable than the higher ash ones. However, the ash contents of fractions less than 0.15 mm increase in ash with decrease in size due to the presence of clay particles.

HEAT VALUE

Thermal content can be reliably expressed as a linear function of the ash content of a given coal. The ash and thermal content of different densities and size fractions were used to establish the following relationship (Appendix A).

$$kJ/kg(db) = 31560 - 341.9*Ash$$

where ash is expressed in per cent.

A minimum heat value of 26271 kJ/kg (11295 Btu/lb) is required for the clean coal product. This corresponds to 15.47% ash (db) and equivalent to 12.5% ash as received basis (8.08% moisture a.r.b.).

WASHABILITY

Washability analyses were carried on three fractions with top size ranges of 200 mm, 50 mm and 12.7 mm. The coarse size ranges (200 and 50 mm) would represent the raw coal that might be washed in a commercial size plant. The minus 12.7 mm washabilities represents the raw coal being fed to the pilot plant. Washability curves of the 200 x 0.6 mm in Fig. 1 (data in Table 4 represent float-sink analysis on raw coal after wet attrition test) indicate a theoretical recovery of 80% by mass at 15.47% ash (12.5% a.r.b.). Washability curves of the 50 x 0.6 mm (after reducing the top size from 200 to 50 mm, on as received sample i.e. not after wet attrition) indicate less recovery (69%) than the 200 mm top size (after wet attrition) due to the presence of embedded clays (Fig. 2). For the 0.6 x 0.15 mm fraction, washability data (Fig. 3) indicate high recovery of 89% at 15.47% ash. Washability curves of the 12.7 x 0.6 mm (after reducing the top size from 200 to 12.7 mm) indicate slight change in coal washability that reflect an increased recovery from 69% (50 x 0.6 mm) to 70% by mass (Table 5 and Fig. 4). However, the recovery of the 0.6 x 0.15 mm is decreased from 89% (0.6 x 0.15 mm fraction of 50 mm x 0) to 87% at the required ash level (Table 6 and Fig. 5). This is due to release of high ash particles from coarser fractions by crushing to the size range of 0.6 x 0.15 mm.

The overall effect of crushing the ROM top size from 200 mm to 50 and then to 12.7 mm is examined. Fig. 6 shows only the 50 mm and 12.7 mm before attrition (200 mm top size washability was only carried after wet attrition) and indicates no significant improvement in coal washability as a result of crushing. As a result, it would be beneficial to wash the coal as coarse as possible. This would simplify plant design and reduce dewatering and drying costs.

COAL FRIABILITY

Estimation of the coal friability is essential at an early stage of development for preparation plant design, dust control and handling of coal. Several direct and indirect methods are available to predict coal degradation. The Australian wet attrition test is used to predict the

amount of degradation (2). The test treats raw coal on a laboratory scale under conditions simulating commercial wash plant treatment. A 50 kg sample of raw coal is tumbled with 150 kg of water along with a standard number of 50 mm steel cubes in a steel drum of 200 L capacity at 20 rpm. Tumbling duration range between 1 to 7 min to represent the retention time in wash plants. Size distributions before and after the attrition test are compared to determine the degree of size degradation. The actual degradation during processing in the pilot plant is determined by comparing reconstituted feed (clean coal + coarse reject + fine reject) and raw feed size consist. Also the ΔP index measurement is used to predict the amount of minus 0.6 mm in the future run-of-mine. Fig. 6 shows the effect of crushing and attrition on coal washability of three top size ranges of 200, 50 and 12.7 mm. The release of clays due to wet attrition is more significant than reduction of top size crushing in improving coal washability. Also there is a limited change between washabilities of the minus 200 mm and 50 mm after wet attrition possibly due to difference in attrition time (7 min for the minus 50 mm and 1 min for the minus 200 mm). However, the washability of minus 12.7 mm indicates an increase of 8% and 5% in recovery over the minus 200 and 50 mm respectively due possibly to increase in surface area that encourages release of embedded clays. Fig. 7 shows size distribution before and after attrition in the 50 mm x 0.

PERFORMANCE PREDICTION

In practice, recoveries would be lower than the theoretical recoveries because of errors of separation inherent in any process. The effect of these errors of separation can be seen from the predicted results of washing in Fig. 8 for the plus 0.6 mm fraction. These predictions cover the dp range of 1.40 to 1.80 relative densities. The probable error (r) is a parameter used in prediction caluclations to convert the theoretical results (from washability curves) into the practical results which one could expect from the actual process. The prediction curves include heavy medium cyclone (HMC) and Baum jig. These predictions are necessary to determine pilot plant flowsheet and setting of equipment parameters to achieve the cleaning objectives. From the curves, it appears likely that in practice (not including the effect of clay release on coal washability improvement) a washed coal with 15.5% ash (26271 kJ/kg) would be obtained

with a thermal recovery of 94.3 and 90.1 per cent in kJ for HMC and Baum jig with corresponding dp of 1.72 and 1.60 respectively.

WASHING TESTS

The processing of the Bryan Mountain coal sample at the Fuel Processing Laboratory pilot plant facilities included feed preparation, two cleaning circuits, dewatering and water treatment. A detailed description of the 10 tonne/hr. pilot plant facility has been reported earlier (3) and a simplified flowsheet is shown in figure 9. The following is a brief outline of the pilot plant circuits.

Feed Preparation: The raw coal is prepared to a 12.7 mm top size by screening out the -10 mm coal and recombining it with +10 mm fraction which has been crushed in a hammer mill.

Cleaning: a) Coarse coal circuit: The bulk raw coal slurry 12.7 mm X 0 has the minus 0.5 mm fraction removed before processing in a Batac jig. The Batac jig produces a reject product, a middlings which is recirculated and a coarse clean coal product.

b) Fine coal circuit: The -0.5 mm fraction which was removed before coarse coal cleaning is processed in a two stage 200 mm diameter water only cyclone. After screening, the -0.15 mm fraction is directed to the water recovery circuit.

Dewatering: The coarse and fine clean coal fractions are combined and dewatered together in a pusher-type centrifuge. The thickener underflow or fine reject is dewatered in a solid bowl centrifuge while the coarse reject is dewatered over a 0.6 mm vibrating screen.

Water treatment: Process water containing classifying cyclone overflow, compound water cyclone underflow and Derrick screen underflow is treated in a bottom fed thickener to produce clarified water for recirculation. The thickened fine reject is then dewatered in a solid bowl centrifuge.

TEST PROCEDURE

The objective of the pilot plant washing tests was to evaluate the performance of the Batac jig in cleaning smalls coal (12.7 x 0.6 mm) to determine size degradation during washing and to produce clean coal with approximately 12 - 13% ash (a.r.b.) equivalent to 26271/kJ/kg. Optimum thermal recovery was the main criterion in setting the separation cutpoints of both the smalls and fines (minus 0.6 mm) cleaning circuits. A total of four tests were run with some changes in dp settings (Table 7). Froth flotation was not included in the fines circuit due to high ash content (72.1%) in the minus 0.15 mm. The new cutpoint adjustment system for the Batac jig was tested and evaluated by comparing the set dp and actual dp from distribution curves.

After the initial adjustment of the Batac jig and cyclones settings, a short preliminary run was made and samples collected for analysis to determine if further adjustment of the equipment was required. Incremental samples were taken of the raw coal, clean coal and reject products for all tests. The end products of the long runs and some of the intermediate products were collected to evaluate the overall performance of the plant and determine material balance.

The ash and moisture contents of the samples were determined following each test run. Screen and float-sink analyses on samples of the main runs were carried out by the Birtley Engineering Laboratory in Calgary along with attrition tests.

DISCUSSION OF RESULTS

A total of 8.62 tonne of raw coal with 36.09% ash has been washed in the pilot plant and produced clean coal yield of 61.01% with 11.34% ash (Table 8). Average thermal recovery was 90.29%. All minus 0.15 mm in the raw coal with 72.1% ash was not cleaned and reported entirely to the fine reject with little or no effect on thermal recovery of clean coal.

PLANT PERFORMANCE

Plant performance is defined by the probable error (r) which reflects the sharpness of separation at a given cutpoint (dp). These parameters are derived from the distribution curve. The distribution curve is a plot of the percentage of the feed to a washing unit that reports as refuse versus the relative density. The cutpoint (dp) is defined as the relative density at which 50% of the feed reports to refuse and 50% to product. The probable error (r) for a distribution curve is one half the difference of the relative density interval at the ordinates of 25 and 75 per cent and this is a measure of the slope of the middle portion of the distribution curve. The better the separation, the steeper the slope of this curve and the smaller the probable error.

Batac Jig Performance

Table 9 shows the summary of two Batac jig tests performance for dp of 1.60. Error curves related to the two size ranges of 12.7 x 2 mm and 2 x 0.6 mm fractions are shown in Figure 10 and combined in Fig. 11. As can be expected dp and r increased with decrease in size, 1.56 and 0.10 (dp,r) for the 12.7 x 2 mm fraction compared to 1.82 and 0.12 for the 2 x 0.6 mm fraction respectively (test 2). The average r from two tests is 0.12 corresponding to 1.60 average dp (Table 9) for the 12.7 x 0.6 mm size range. The increase in r and dp due to decrease in size range from 12.7 x 2 mm to 2 x 0.6 mm appears not as significant as with other coals. This is possibly caused by the presence of clays that might have reduced turbulance in jig's pulsation due to moderate increases in viscosity resulting in better separation of fine particles. Batac jig results from tests 2 and 3 are compared with predicted performance from a heavy medium cyclone and Baum jig (Fig. 8). Test results indicate better results than theoretical ones. This can be explained by clays release during washing resulting in improved coal washability as indicated earlier in Fig. 6.

The new system for setting the Batac jig dp is tested and compared with the dp determined from error curves. The new system includes a ring of relative density equal to the dp that would float between the reject and clean coal beds and a change in height below or above the set height would trigger the opening or closing of the reject gate. Table 9 data indicate that ring relative density is comparable to the measured relative density of separation for 12.7 x 0.6 mm and the variation between

tests 2 and 3 may be caused by change in size distribution. It is noted that the coarse fractions (12.7 x 2.0 mm) show actual lower dp than jig set dp and vise versa for the fines fractions (2.0 x 0.6 mm). However, the overall average dp is identical to the set dp of 1.60 (Table 9).

Water-Only-Washing Cyclone Perfomance:

The two stage water-only cyclones (WOC) are set to separate at high dp to mostly scalp particles heavier than 2.0 relative density. The two stage WOC produced the desired high ash reject (61.3 - 63.9% ash) with r ranging between 0.19 to 0.22 at dp of 2.01 to 2.04 respectively. It appears that the presence of moderate amounts of clays has no harmful effect on separation efficiency as a result of increased viscosity (5). All minus 0.15 mm fraction with 72.1% ash is removed and reported to water recovery section of the pilot plant.

SIZE DEGRADATION

Changes in screening characteristics resulting from degradation during washing can be evaluated by comparing the analyses of raw coal and reconstituted feed. The reconstituted feed is obtained by combining the individual product size analyses, weighted according to their respective mass yields. The screen analysis of the reconstituted feed as compared with the raw feed analysis (Table 3) and wet attrition tests for 1 and 7 min (Fig. 12) indicates considerable change in size consist. Degradation during pilot plant washing increased the amount of minus 0.6 mm from 21% to 29% (for 12.7 mm x 0). The wet attrition test (12.7 mm x 0) shows 28% and 31% by mass of minus 0.6 mm for 1 and 7 min tests respectively. Attrition during washing is comparable to the one resulting from attrition tests. However, size distribution of the washing test (Fig. 12) varies from attrition tests in the fines fractions due to possible losses of clays in the system.

The predicted amount of minus 0.6 mm in the run-of-mine (ROM) from ΔP index measurement (ΔP=11.6) is 22.8% by mass, as calculated from the following equation (4):

$$\text{Mass \% of } -0.6 \text{ mm in ROM} = 14.90 + 0.68\,\Delta P$$

The amount of fines generated by wet attrition of 50 mm x 0 for 7 minutes was 27.8% (Fig. 7). The difference between the two values could be

explained as follows:

1. The attrition test is carried on 50 mm x 0 while the ROM is expected to be coarser than 50 mm top size. It is projected that the amount of minus 0.6 mm in ROM with 200 mm top size to be less than 27.8%.
2. Considerable amounts of clays are released during wet attrition and contributed to the higher amounts of fines (27.8%) than the one predicted by ΔP (22.8%) which reflects coal degradation rather than clays release.

PROPOSED FLOWSHEET

Washability data used for flowsheet calculations are based on float-sink data after 7 min wet attrition test which simulate the coal washability and clays release during washing. Washability of the 50 x 12.7 mm fraction (Appendix A) are different from that of 12.7 x 0.6 mm (Appendix A) where clean coal with 15.47% ash can be achieved at 1.63 dp for the 50 x 12.7 mm and about 2.25 dp for the 12.7 x 0.6 mm (theoretical dp) respectively. As a result it is suggested that the plus 12.7 mm should be washed separate from the 12.7 x 0.6 mm.

The suggested schematic flowsheet in Fig. 13 is expected to produce clean coal at 15.5% ash equivalent to 26271 kJ/kg. The flowsheet includes three steps of cleaning:

1. Heavy medium bath (HMB) cleans the plus 12.7 mm and removes most of the large pieces of clays before disintegrating in water. The HMB is recommended over a jig to minimize losses in thermal recovery that can be expected when jig is used due to high amounts of near density material (Fig. 14).
2. Batac jig cleans the 12.7 x 0.6 mm at dp of 2.0 or higher. The heavy medium cyclone is not recommended due to high dp and associated increased viscosity along with expected high magnetite losses in presence of high amounts of clays.
3. Water only cyclone (WOC) cleans the 0.6 x 0.15 mm at high dp after being deslimed to remove clays that might cause deterioration in the washing cyclone's performance (5). The minus 0.15 mm fraction is high in ash (78.2%) and can be discarded.

As shown earlier (Fig. 6), there is a limited difference between washabilities after attrition of raw coal crushed to minus 200 mm and minus

50 mm. Therefore, it is beneficial to wash the raw coal at the coarser size (-200 mm) to minimize dewatering and drying cost and also achieve better separation efficiency. Performance predictions of HMB for the plus 12.7 mm, HMC and jig for the 12.7 x 0.6 mm fraction and WOC for the 0.6 x 0.15 mm fraction are shown in Figures 14, 15 and 16. The performance predictions are based on the minus 50 mm washability after attrition because similar washabilities on the minus 200 mm were not available. However, this deviation between the calculated recoveries should not be significant. Based on the suggested schematic flowsheet (Fig. 13) and Figures 14, 15 and 16 the overall heat recovery is expected to be approximately 90.7% which is equivalent to 62.9% by mass.

CONCLUSIONS AND RECOMMENDATIONS

1. A limited improvement in coal washability would be achieved by crushing the raw coal from 200 mm to 50 mm and then to 12.7 mm top sizes. For the 50 mm top size, the 15.47% ash (equivalent to 12.5% ash on a.r.b.) level can be theoretically achieved at 1.73 dp for the 50 x 0.6 mm fraction and higher than 2.2 dp for the 0.6 x 0.15 mm fraction respectively.
2. Both pilot plant testing and wet attrition tests indicate an increase of 8 - 9% by mass in the amount of minus 0.6 mm fraction mostly as a result of clays release and partly to limited size degradation. The amount of minus 0.6 mm predicted for future run-of-mine raw coal is 22.8% by mass as calculated from ΔP index measurement. However, the amount produced by wet attrition is 27.8% by mass.
3. Batac jig testing for the 12.7 x 0.6 mm shows better performance than can be expected from a Baum jig model (which is based on washability before wet attrition) due to possible release of clays and improvement in raw coal washability. The average probable error is 0.12 at 1.60 dp. Limited presence of clays might have contributed to the relatively good recovery of fine coal particles in the jig and water-only cyclone. In the jig: the 2 x 0.6 mm fraction is washed at 1.8 dp with r = 0.12

which is considered good for that size range and in the WOC, the 0.6 x 0.15 mm is washed at 2.0 dp with r = 0.19 - 0.22 which is considered acceptable. It is reasonable to state that moderate amounts of clays can be beneficial for the separation of fine particles possibly as a result of reduced turbulences.

4. Based on coal characteristics and pilot plant testing an outline of a flowsheet is proposed, which includes two processes for coarse cleaning: heavy medium bath for the 200 x 12.7 mm and Batac jig for 12.7 x 0.6 mm. For fines cleaning, water-only cyclone is suggested for the 0.6 x 0.15 mm and the minus 0.15 mm removed as discard. The overall thermal recovery is expected to be 90.7% (equivalent to 62.9% by mass) to produce clean coal with 26271 kJ/kg (15.47% ash or 12.5% ash on a.r.b.).

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Table 1 - Analysis of CNR - Bryan Mountain composite sample (50mm x 0)

	As Rec'd	Dry (db)
Moisture	8.08	-
Ash (%)	37.25	40.52
Volatile Matter (%)	23.51	25.58
Fixed Carbon (%)	31.16	33.90
Na (%)	0.0040	0.0044
K (%)	0.0095	0.0103
kJ/kg (det.)	16474	17932
Sulphur (%)	0.18	0.19
Sulphur (kg/MkJ)	0.109	-
Hardgrove Grindability Index	61.9	-

Table 2 - Size consist of CNR - Bryan Mountain raw coal (50mm x 0)

Particle Size mm	Mass %	Ash %	kJ/kg	Cumulative		
				Mass %	Ash %	kJ/kg
+25	14.77	44.66	16474	14.77	44.66	16474
25 - 12.7	14.99	33.84	20219	29.76	39.21	18361
12.7 - 6.3	13.55	32.97	20641	43.31	37.25	19075
6.3 - 3.35	14.62	35.13	19638	57.93	36.72	19217
3.35 - 2	16.55	38.11	18873	74.48	37.03	19140
2 - 0.6	14.57	43.34	17080	89.06	38.06	18803
0.6 - 0.15	3.53	28.89	21547	92.58	37.71	18908
0.15 - 0.074	0.96	49.08	14979	93.54	37.83	18868
0.074 - 0.044	0.75	64.02	9184	94.29	38.04	18791
-0.044	5.71	81.53	3597	100.00	40.52	17923
Total	100.00	40.52	17923	-	-	-

Mean particle size = 11 mm

Table 3 - Size Analysis of raw feed to the pilot plant (12.7mm x 0)

Particle Size mm	Mass %	Ash %	Cumulative	
			Mass %	Ash %
+12.7	0.60	62.27	0.60	62.27
12.7 - 6.3	5.24	44.75	5.83	46.54
6.3 - 3.35	19.74	34.40	25.58	37.17
3.35 - 2.0	29.34	31.83	54.91	34.32
2.0 - 0.6	24.26	30.36	79.17	33.10
0.6 - 0.15	9.83	24.95	89.00	32.20
0.15 - 0.075	1.52	42.48	90.52	32.38
0.075 - 0.044	1.22	58.27	91.73	32.72
-0.044	8.27	79.57	100.00	36.59
Total	100.00	36.59	-	-

Table 4 - Washing characteristics of CNR coal - Bryan Mountain after wet attrition 200 x 0.6 mm

Relative Density Fractions	Elementary data			Cumulative data					
				Float			Sink		
	Mass%	Ash%	kJ/kg	Mass%	Ash%	kJ/kg	Mass%	Ash%	kJ/kg
Float- 1.30	1.75	2.70	30637	1.75	2.70	30637	100.00	29.62	21433
1.30 - 1.35	27.96	4.89	29888	29.71	4.76	29932	98.25	30.10	21269
1.35 - 1.40	22.32	10.85	27850	52.03	7.37	29039	70.29	40.13	17840
1.40 - 1.45	7.52	16.41	25949	59.55	8.51	28649	47.97	53.75	13183
1.45 - 1.50	6.11	22.26	23949	65.66	9.79	28211	40.45	60.69	10809
1.50 - 1.55	3.49	27.62	22117	69.15	10.69	27904	34.34	67.53	8472
1.55 - 1.60	1.97	31.91	20650	71.12	11.28	27703	30.85	72.05	6928
1.60 - 1.70	3.85	38.96	18240	74.97	12.70	27217	28.88	74.78	5992
1.70 - 1.80	2.33	49.91	14496	77.30	13.82	26833	25.03	80.29	4108
1.80 - 1.90	2.82	58.82	11449	80.12	15.41	26292	22.70	83.41	3042
1.90 - Sink	19.88	86.90	1849	100.00	29.62	21433	19.88	86.90	1849

Table 5 - Washing characteristics of CNR coal - Bryan Mountain 12.7 x 0.6 mm (79.17% of total)

Relative Density Fractions	Elementary data			Cumulative data					
				Float			Sink		
	Mass%	Ash%	kJ/kg	Mass%	Ash%	kJ/kg	Mass%	Ash%	kJ/kg
Float- 1.30	0.20	3.35	30415	0.20	3.35	30415	100.00	33.38	20147
1.30 - 1.35	8.91	3.94	30213	9.11	3.93	30217	99.80	33.44	20127
1.35 - 1.40	21.99	7.12	29126	31.10	6.18	29446	90.89	36.33	19138
1.40 - 1.45	12.62	14.90	26466	43.72	8.70	28586	68.90	45.66	15950
1.45 - 1.50	8.76	18.97	25074	52.48	10.41	27999	56.28	52.55	13592
1.50 - 1.60	12.49	28.04	21973	64.97	13.80	26841	47.52	58.74	11475
1.60 - 1.70	5.36	38.14	18520	70.33	15.66	26207	35.03	69.69	7732
1.70 - 1.80	5.17	49.46	14650	75.50	17.97	25415	29.67	75.39	5783
1.80 - 2.00	5.84	61.66	10478	81.34	21.11	24343	24.50	80.86	3912
2.00 - 2.17	4.92	78.40	4755	86.26	24.38	23226	18.66	86.88	1858
2.17 - Sink	13.74	89.91	820	100.00	33.38	20147	13.74	89.91	820

Table 6 - Washing characteristics of CNR coal - Bryan Mountain 0.6 x 0.15 mm (9.83% of total)

Relative Density Fractions	Elementary data			Cumulative data					
				Float			Sink		
	Mass%	Ash%	kJ/kg	Mass%	Ash%	kJ/kg	Mass%	Ash%	kJ/kg
Float- 1.30	1.90	2.95	30551	1.90	2.95	30551	100.00	25.09	22982
1.30 - 1.35	25.88	3.66	30309	27.78	3.61	30326	98.10	25.52	22836
1.35 - 1.40	15.47	5.70	29611	43.25	4.36	30070	72.22	33.35	20158
1.40 - 1.45	11.02	8.42	28681	54.27	5.18	29788	56.75	40.89	17581
1.45 - 1.50	6.20	12.28	27361	60.47	5.91	29539	45.73	48.71	14906
1.50 - 1.60	9.19	17.09	25717	69.66	7.39	29035	39.53	54.43	12952
1.60 - 1.70	5.39	24.85	23064	75.05	8.64	28606	30.34	65.73	9086
1.70 - 1.80	3.28	37.14	18862	78.33	9.83	28198	24.95	74.57	6066
1.80 - 2.00	2.89	52.95	13456	81.22	11.37	27673	21.67	80.23	4129
2.00 - 2.17	3.29	67.72	8407	84.51	13.56	26923	18.78	84.43	2694
2.17 - Sink	15.49	87.98	1480	100.00	25.09	22982	15.49	87.98	1480

Table 7 - Summary of products analyses - washing tests (ash contents on dry basis)

Test No.	%	Raw Coal	Clean Coal		Final Products		
			Batac jig	Water-only cyclone	Clean coal	Coarse reject	Fine reject
1	Ash	40.24	8.69	19.12	12.46	-	55.58
	Moisture*	6.80	-	-	13.74	-	26.38
	Yield	-	-	-	-	-	-
2	Ash	36.51	10.16	16.12	11.04	70.95	61.58
	Moisture*	3.30	-	-	7.38	25.33	34.22
	Yield	-	-	-	62.19	23.35	14.46
3	Ash	35.48	10.70	17.28	11.43	72.27	62.25
	Moisture*	8.06	-	-	9.46	-	34.51
	Yield	-	-	-	63.28	22.64	14.08
4	Ash	33.80	9.33	15.28	10.63	52.70	58.23
	Moisture*	8.70	-	-	12.94	26.16	35.31
	Yield	-	-	-	46.14	37.14	16.72

*Total Moisture

Table 8 - Thermal recovery in relation to raw and clean coal quality

Test	Raw Coal		Clean Coal			
	Mass kg	Ash %	Yield %	Ash %	dp (Batac jig)	Thermal Recovery %
1	907.2	40.24	-	12.46	1.60	-
2	2268.0	36.57	62.19	11.04	1.60	90.67
3	4539.1	35.48	63.28	11.43	1.60	90.06
4	907.2	33.80	46.14*	10.63	1.80	-
Total	8621.5	36.09	61.01	11.34	1.60**	90.29**

* The yield is lower than can be expected due to change in size distribution of the feed to the jig resulting in lower dp than set one (1.80).

** Tests 2 and 3 only

Table 9 - Summary of Batac jig performance

Test	Jig Set dp	Actual dp			Performance					
		12.7 x 2 mm	2 x 0.6 mm	12.7 x 0.6 mm	12.7 x 2 mm		2 x 0.6 mm		12.7 x 0.6 mm	
					r*	ea**	r	ea	r	ea
2	1.60	1.56	1.82	1.63	0.10	61	0.12	75	0.13	75
3	1.60	1.53	1.73	1.57	0.09	62	0.13	82	0.11	74
Av.	1.60	1.54	1.77	1.60	0.095	61.5	0.125	78.5	0.12	74.5

* Probable error

** Error area

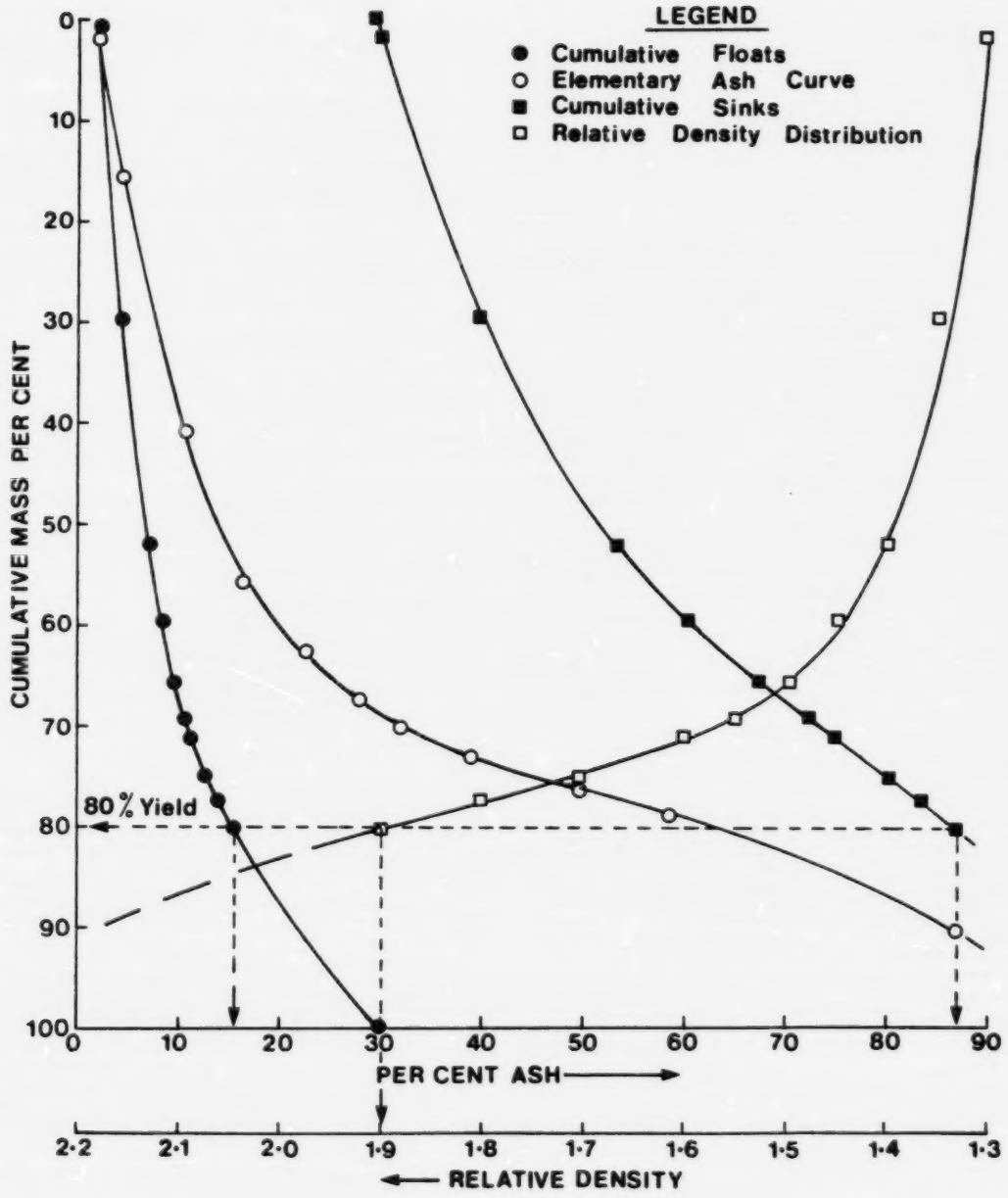

Figure 1 - Washability curves: CNR coal 200 x 0.6 mm after attrition.

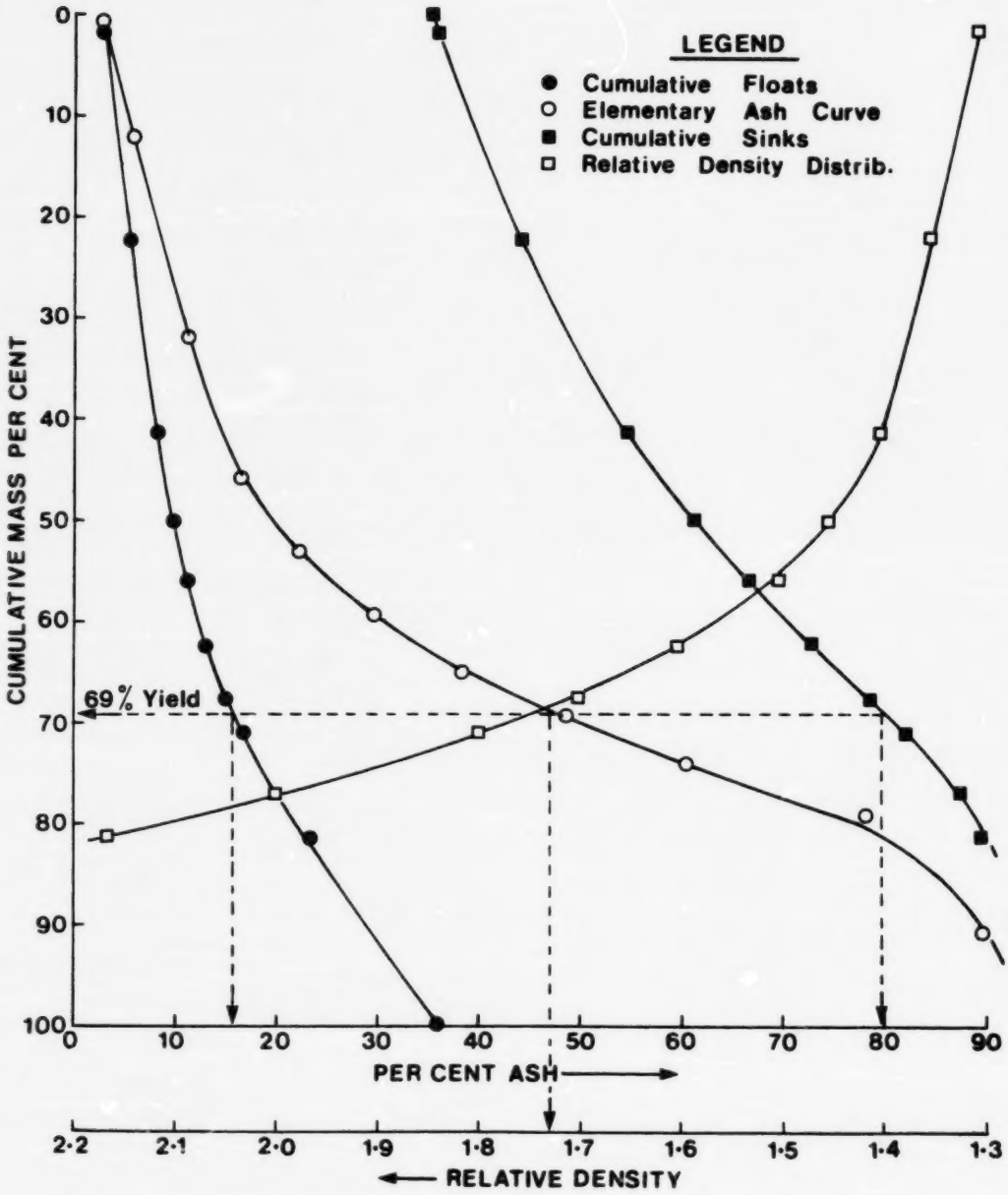

Figure 2: Washability curves: CNR coal 50 x 0.6 mm (89.06% of total).

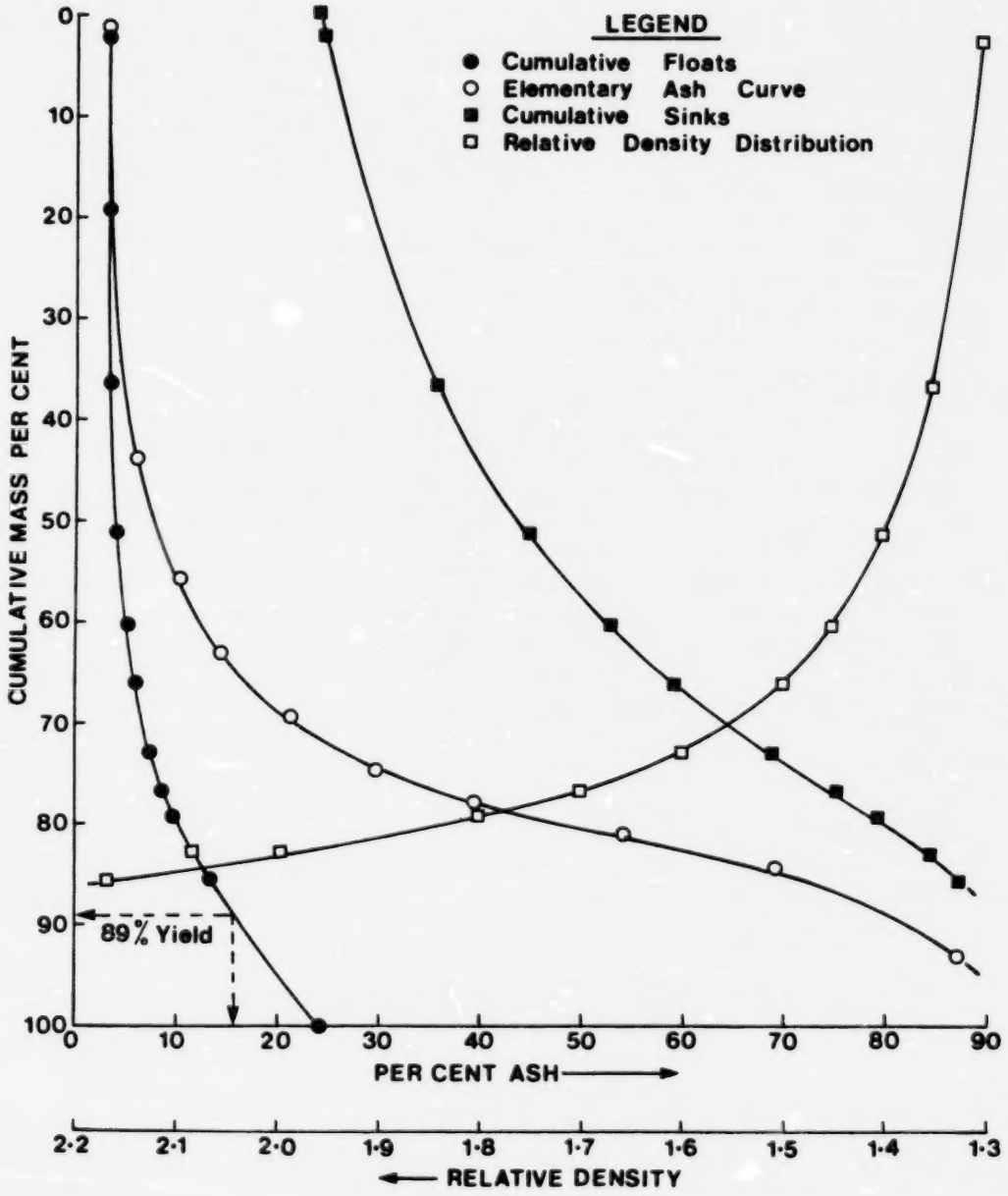

Figure 3 - Washability curves: CNR coal 0.6 x 0.15 mm (3.53% of total).

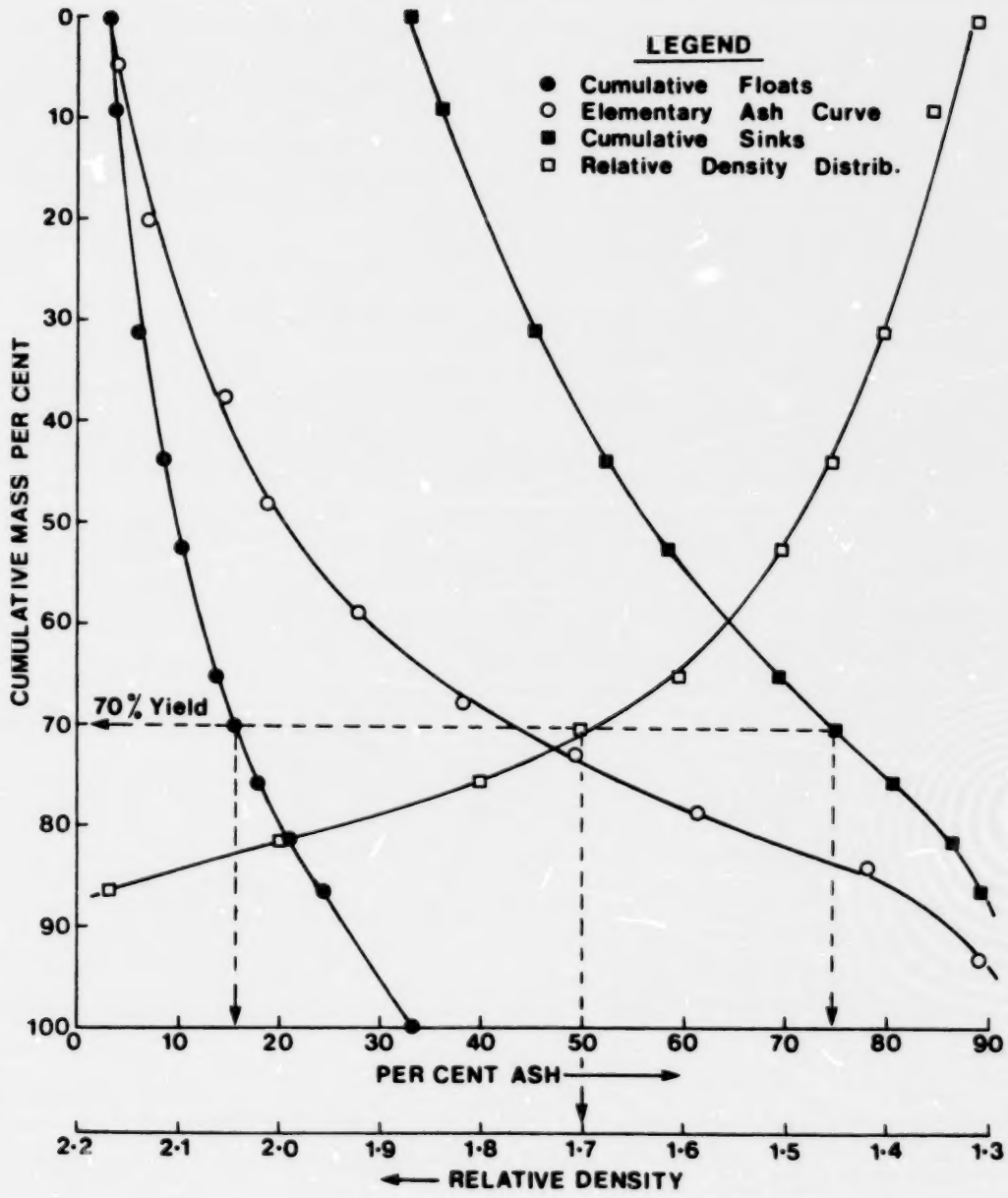

Figure 4 - Washability curves: CNR coal fed to pilot plant 12.7 x 0.6 mm (79.17% of total).

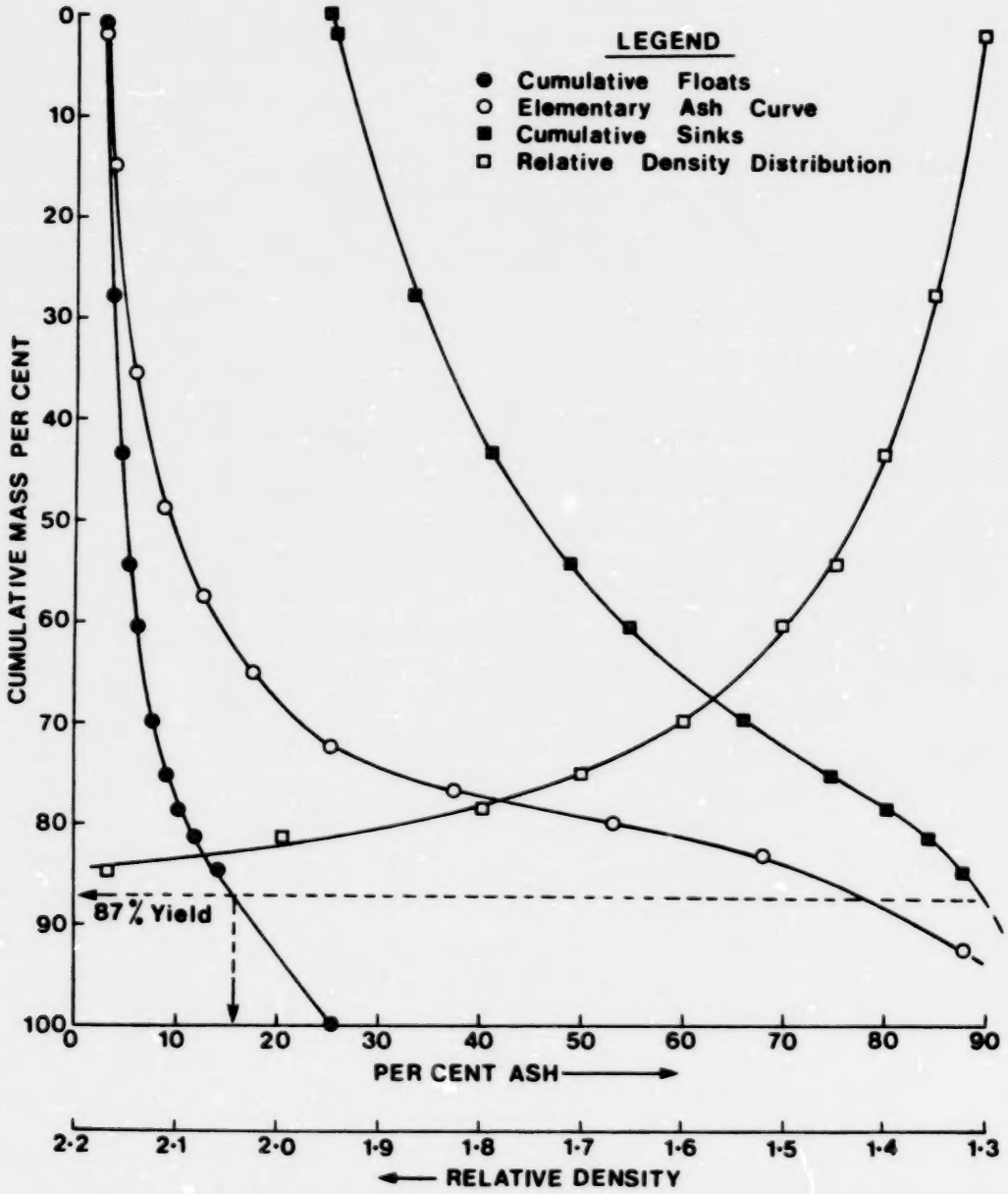

Figure 5 - Washability curves: CNR coal feed to pilot plant 0.6 x 0.15 mm (9.38% of total).

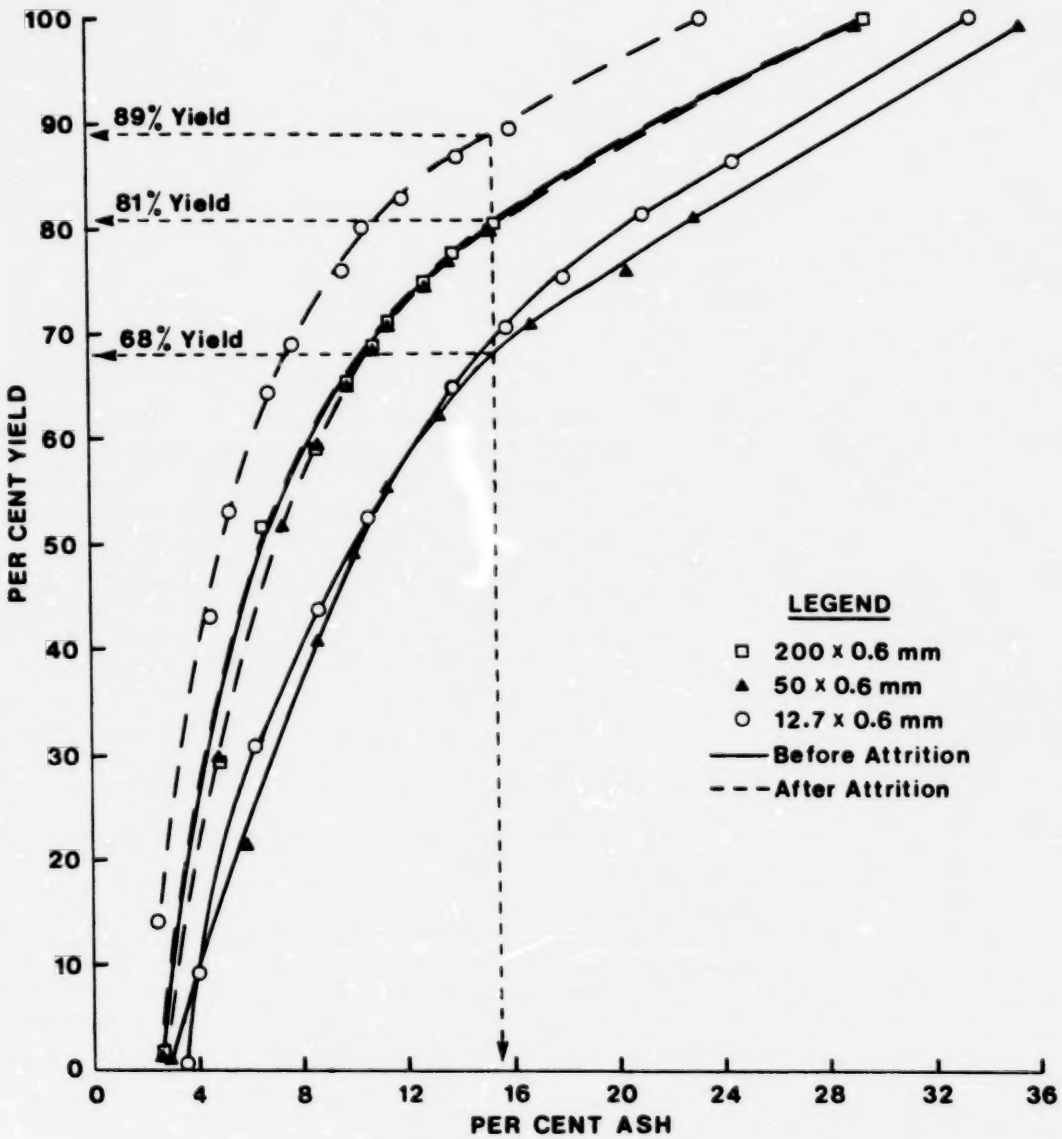

Fig. 6 - Effect of crushing and attrition on Coal washability (+0.6 mm)

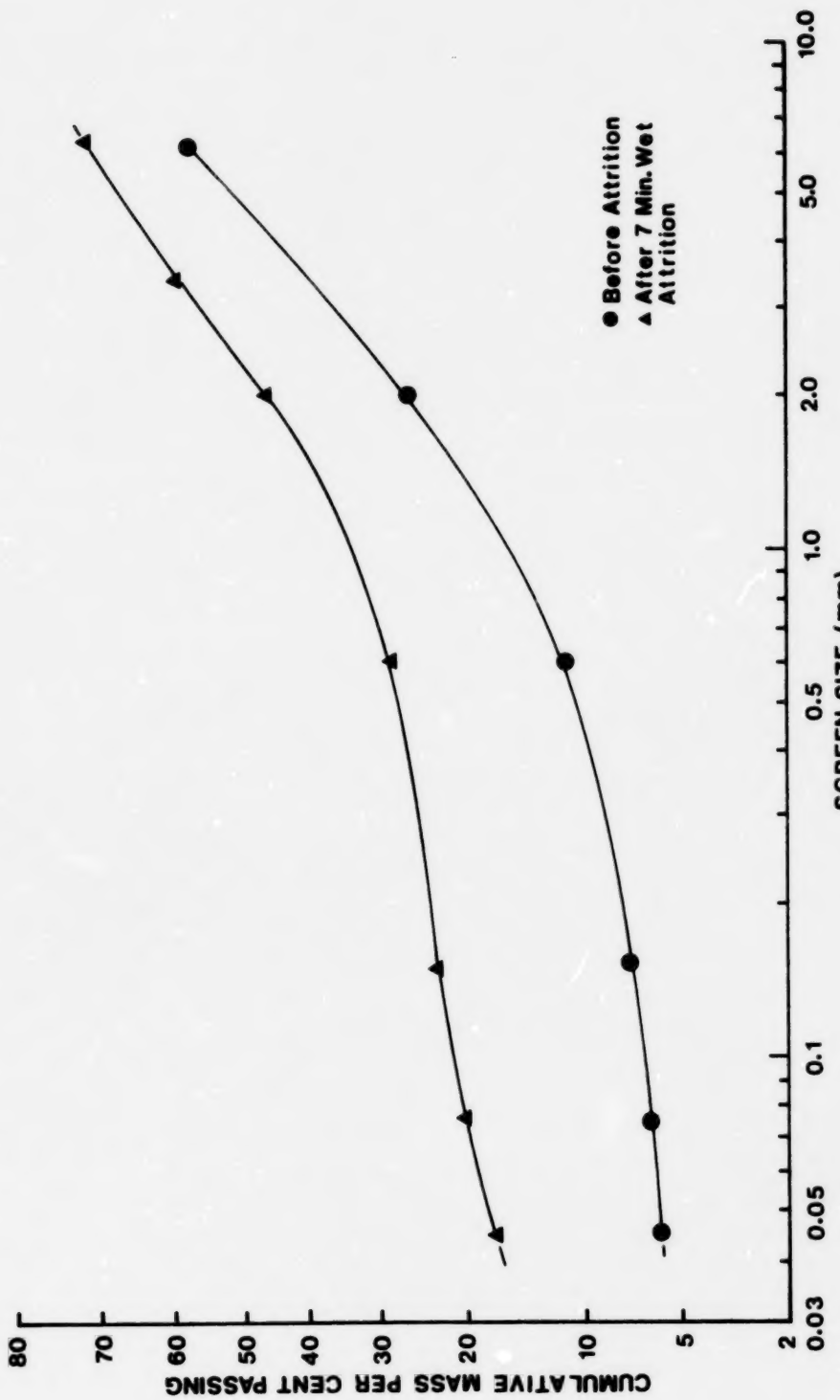

Figure 7 - Size degradation sieve size (mm) during wet attrition tests (50 mm x 0).

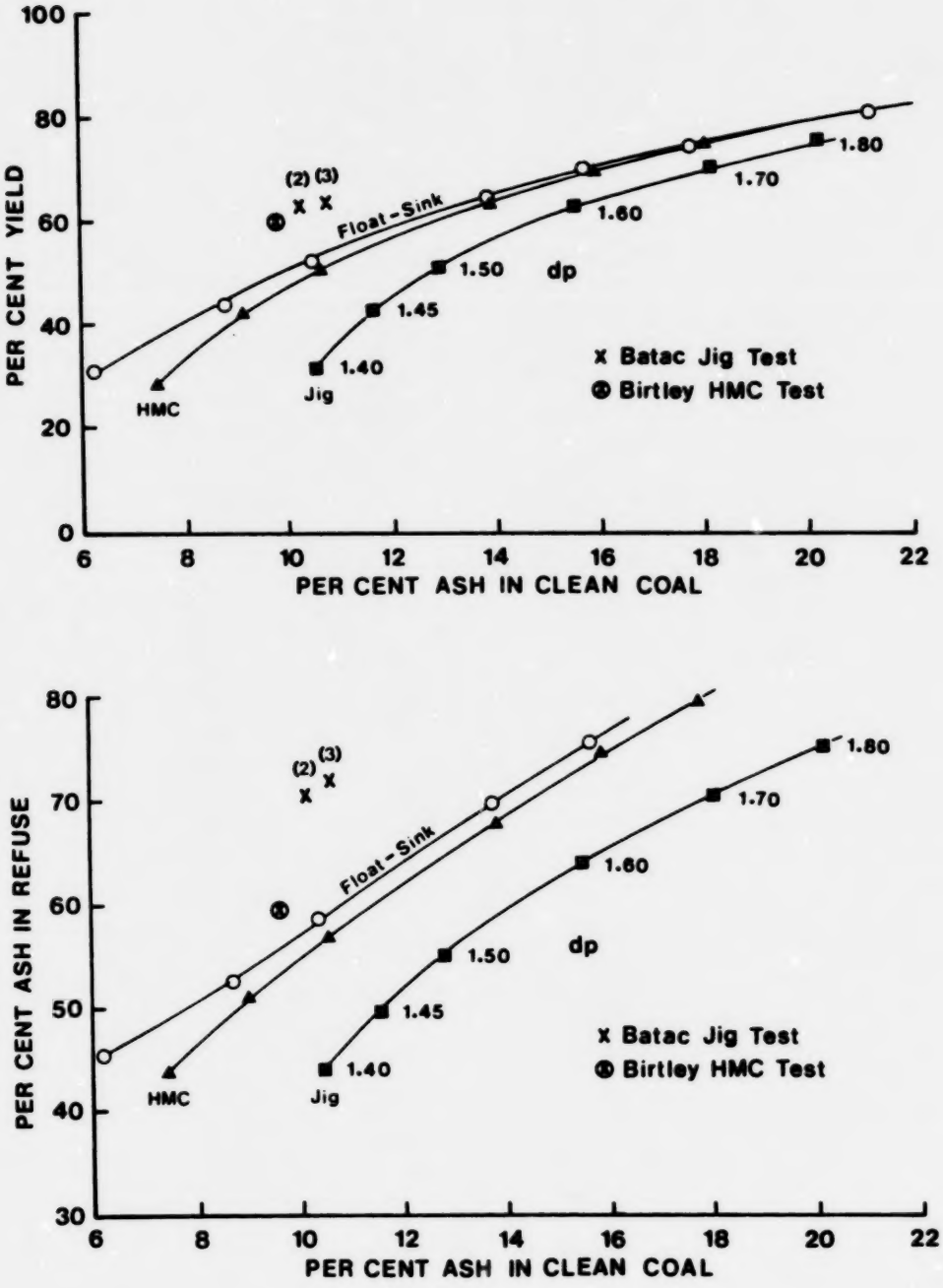

Figure 8 - Performance evaluation prediction (12.7 x 0.6 mm).

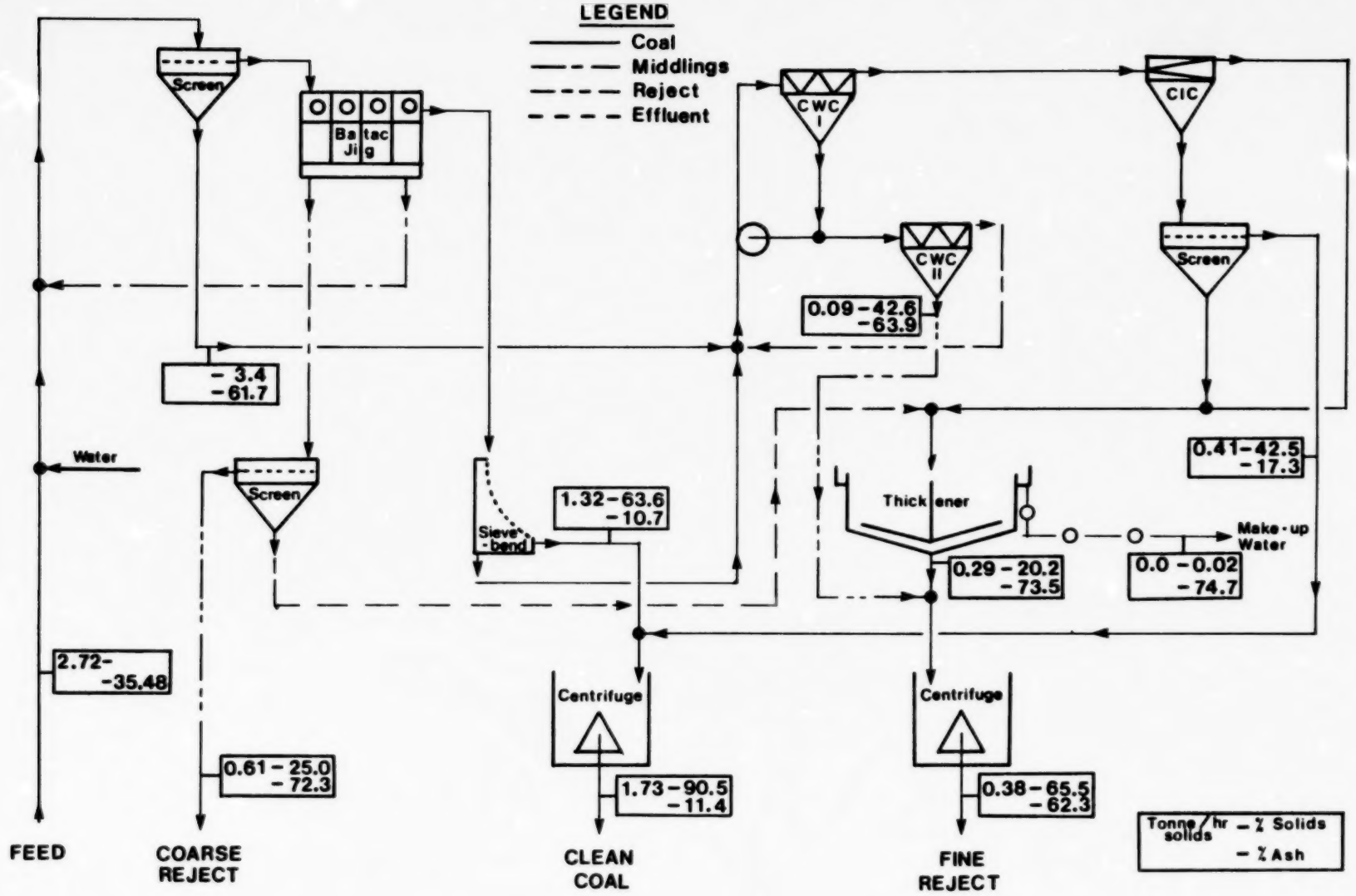

Figure 9 - Simplified pilot plant flowsheet with partial material balance.

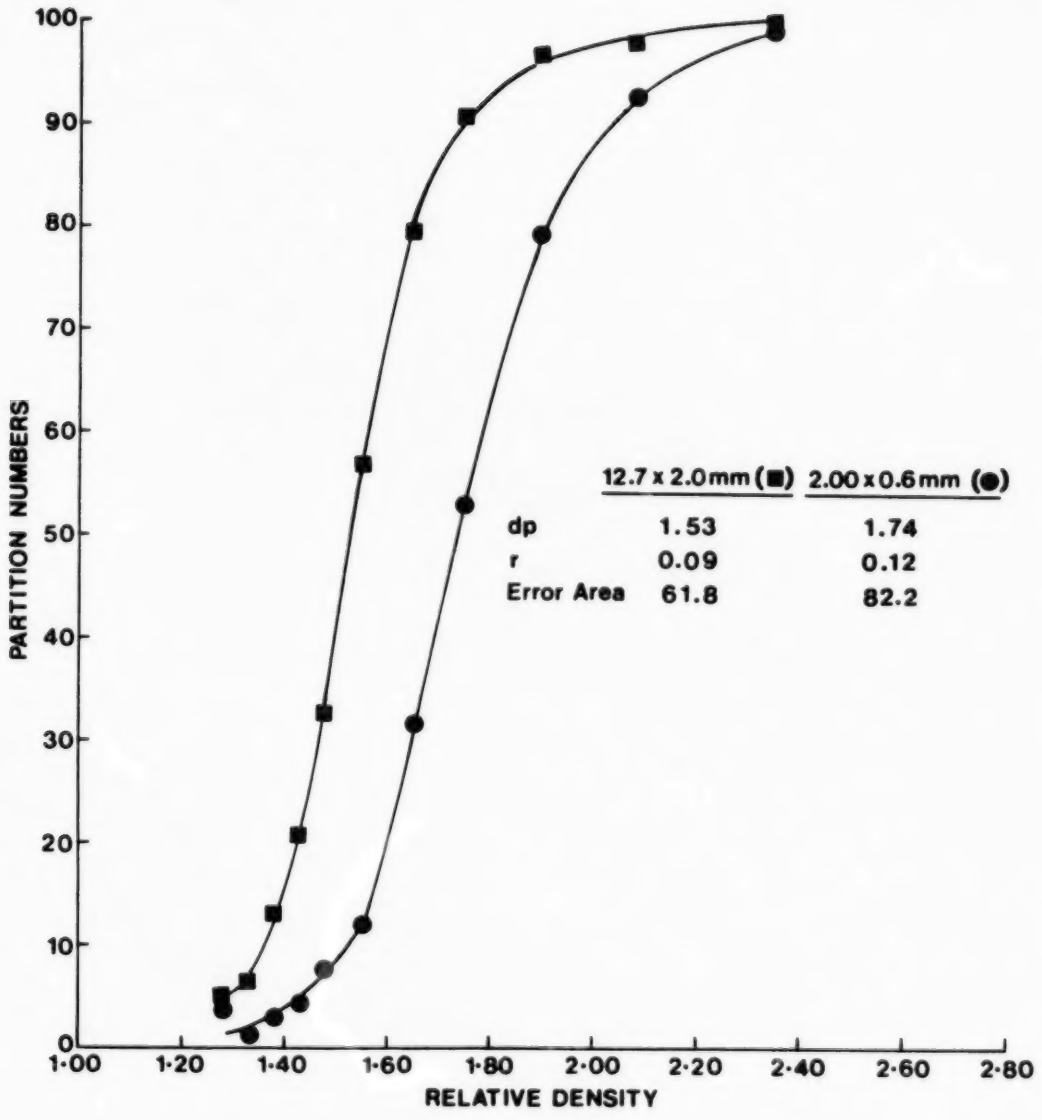

Figure 10 - Error curves for Batac jig.

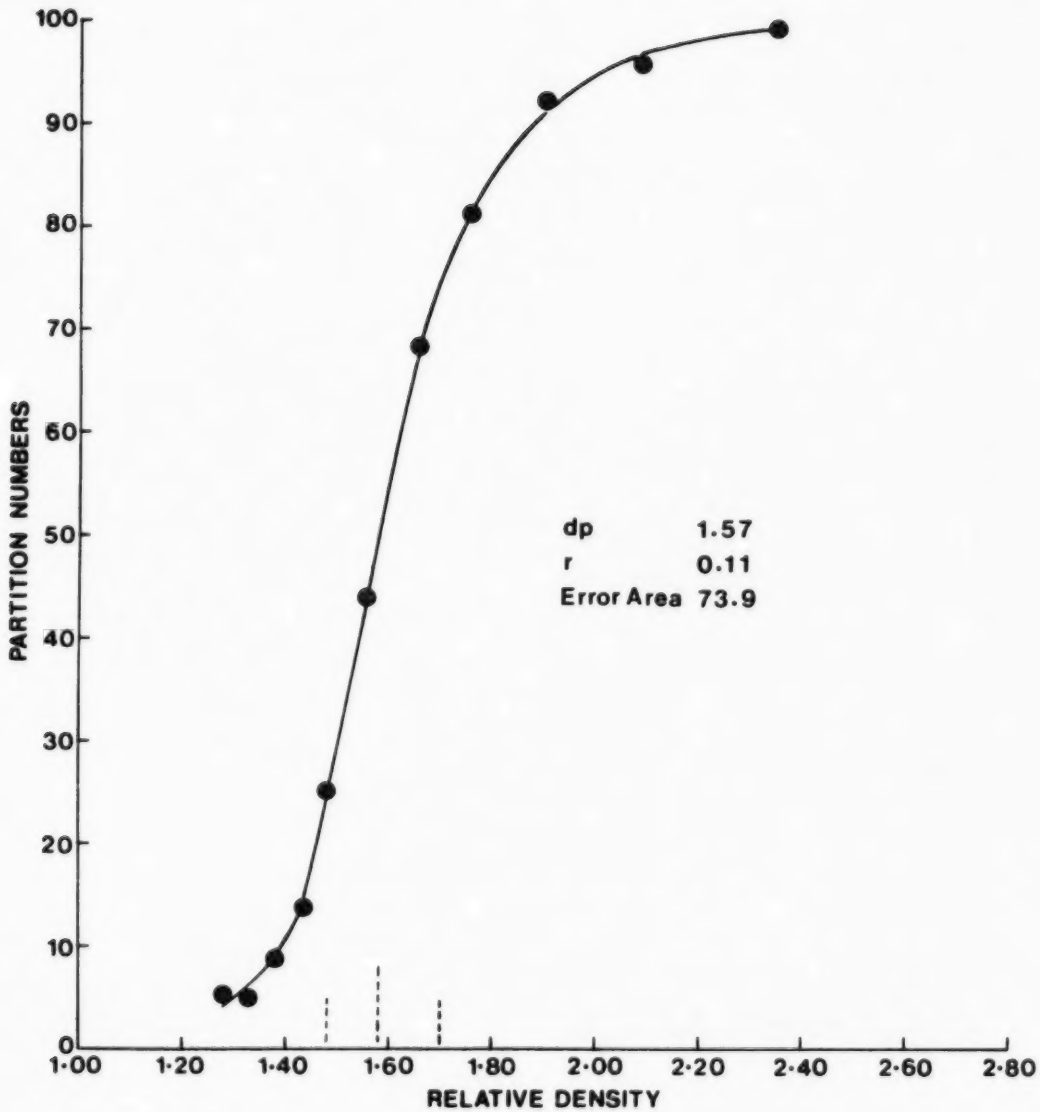

Figure 11 - Error curve for Batac jig 12.7 x 0.6 mm.

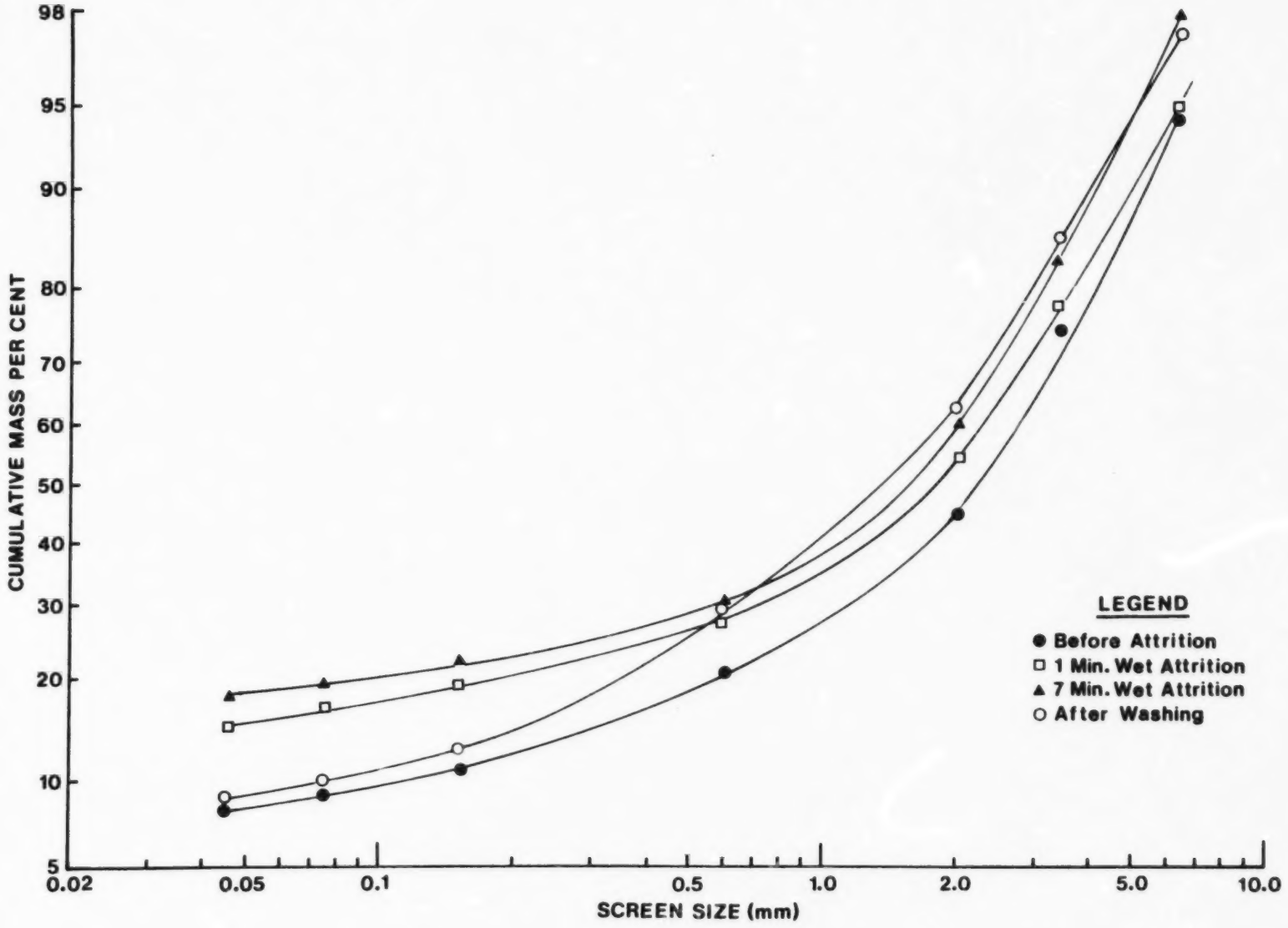

Figure 12 - Comparison between size degradation by attrition and washing tests (12.7 mm x 0).

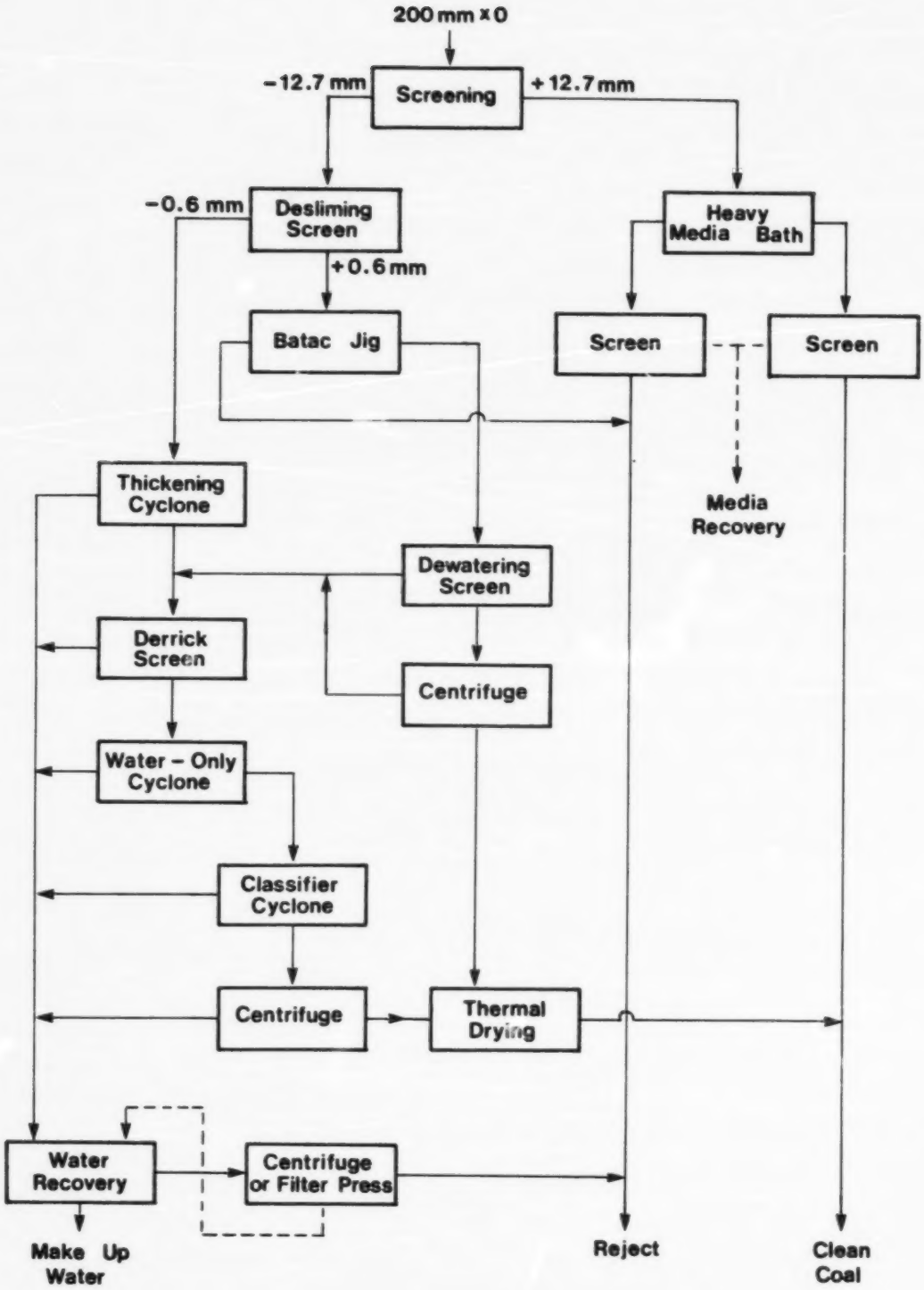

Figure 13 - Schematic of proposed preparation plant - CNR.

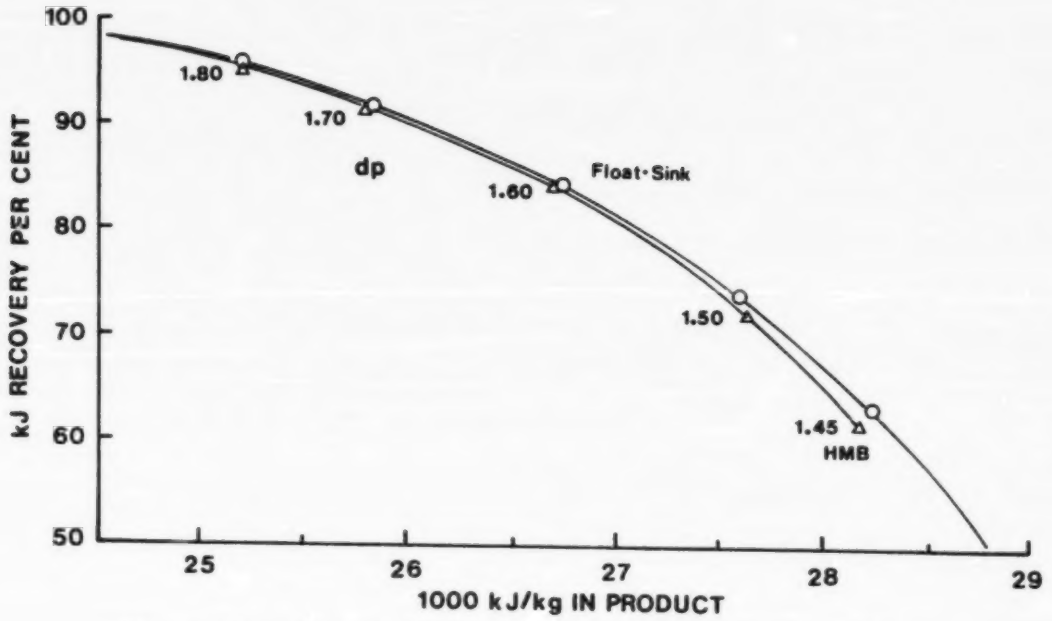

Figure 14 - Thermal recovery prediction (plus 12.7mm).

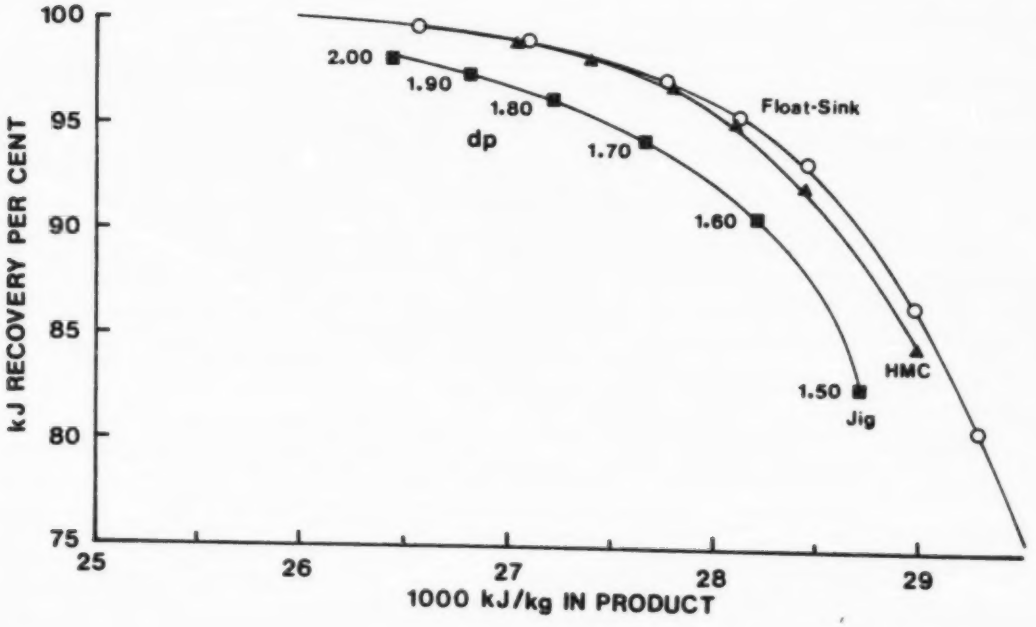

Figure 15 - Thermal recovery prediction (12.7 x 0.6 mm).

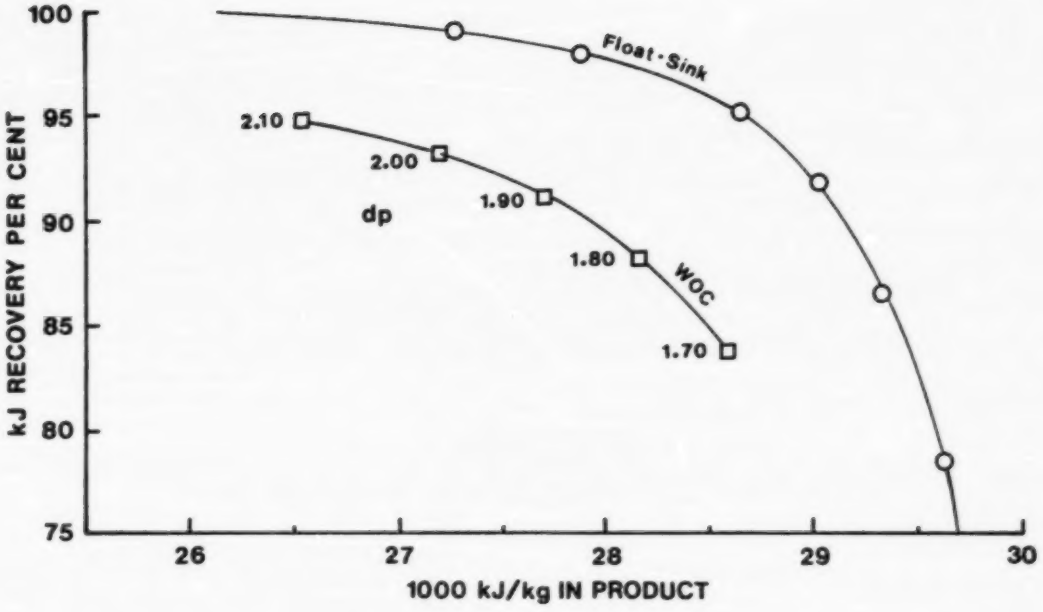

Figure 16 - Thermal recovery prediction (0.6 x 0.15 mm).

APPENDIX A

WASHIBILITY DATA AND ASH - KJ RELATIONSHIP

Table A1 - Washing characteristics of Bryan Mountain coal (50 x 0 mm) after 7 min wet attrition (50 x 12.7 mm - 17.35% of total)

Relative Density Fractions	Elementary data			Cumulative data					
				Float			Sink		
	Mass%	Ash%	kJ/kg	Mass%	Ash%	kJ/kg	Mass%	Ash%	kJ/kg
Float- 1.30	0.10	2.64	30657	0.10	2.64	30657	100.00	41.22	17653
1.30 - 1.35	12.87	5.09	29820	12.97	5.07	29826	99.90	41.26	17640
1.35 - 1.40	12.54	9.18	28421	25.51	7.09	29136	87.03	46.60	15839
1.40 - 1.45	14.08	14.45	26620	39.59	9.71	28241	74.49	52.90	13720
1.45 - 1.50	7.85	21.25	24295	47.44	11.62	27588	60.41	61.87	10714
1.50 - 1.60	8.39	28.38	21857	55.83	14.14	26727	52.56	67.93	8685
1.60 - 1.70	6.89	38.45	18414	62.72	16.81	25814	44.17	75.45	6184
1.70 - 1.80	4.30	45.58	15976	67.02	18.65	25182	37.28	82.28	3923
1.80 - 2.00	6.90	62.91	10051	73.92	22.78	23770	32.98	87.07	2352
2.00 - 2.17	3.18	84.76	2581	77.10	25.34	22896	26.08	93.46	315
2.17 - Sink	22.90	94.67	0	100.00	41.22	17653	22.90	94.67	0

Table A2 - Washing characteristics of Bryan Mountain coal (50 x 0 mm) after 7 min wet attrition (12.7 x 0.6 mm - 54.85% of total)

Relative Density Fractions	Elementary data			Cumulative data					
				Float			Sink		
	Mass%	Ash%	kJ/kg	Mass%	Ash%	kJ/kg	Mass%	Ash%	kJ/kg
Float- 1.30	2.42	2.23	30798	2.42	2.23	30798	100.00	23.20	23628
1.30 - 1.35	34.70	3.91	30223	37.12	3.80	30260	97.58	23.72	23450
1.35 - 1.40	17.33	8.37	28698	54.45	5.25	29763	62.88	34.65	19713
1.40 - 1.45	10.78	13.82	26835	65.23	6.67	29279	45.55	44.65	16295
1.45 - 1.50	5.34	18.68	25173	70.57	7.58	28969	34.77	54.21	13027
1.50 - 1.60	7.00	24.85	23064	77.57	9.14	28436	29.43	60.65	10823
1.60 - 1.70	2.82	37.36	18787	80.39	10.13	28097	22.43	71.83	7002
1.70 - 1.80	2.42	45.69	15939	82.81	11.17	27742	19.61	76.78	5308
1.80 - 2.00	3.63	58.05	11713	86.44	13.14	27069	17.19	81.16	3811
2.00 - 2.17	2.21	73.52	6424	88.65	14.64	26554	13.56	87.35	1696
2.17 - Sink	11.35	90.04	775	100.00	23.20	23628	11.35	90.04	775

Table A3 - Washing characteristics of Bryan Mountain coal (50 x 0 mm) after 7 min wet attrition (0.6 x 0.15 mm - 4.96% of total)

Relative Density Fractions	Elementary data			Cumulative data					
				Float			Sink		
	Mass%	Ash%	kJ/kg	Mass%	Ash%	kJ/kg	Mass%	Ash%	kJ/kg
Float- 1.30	4.60	2.55	30688	4.60	2.55	30688	100.00	24.72	23108
1.30 - 1.35	15.42	3.73	30285	20.02	3.46	30378	95.40	25.79	22743
1.35 - 1.40	22.52	6.02	29502	42.54	4.81	29914	79.98	30.04	21289
1.40 - 1.45	13.92	7.14	29119	56.46	5.39	29718	57.46	39.46	18070
1.45 - 1.50	4.83	8.61	28616	61.29	5.64	29631	43.54	49.79	14538
1.50 - 1.60	6.95	14.39	26640	68.24	6.53	29327	38.71	54.93	12781
1.60 - 1.70	4.90	19.70	24825	73.14	7.41	29025	31.76	63.80	9748
1.70 - 1.80	3.64	30.65	21081	76.78	8.52	28648	26.86	71.84	6998
1.80 - 2.00	4.45	49.42	14663	81.23	10.76	27882	23.22	78.30	4790
2.00 - 2.17	2.68	66.98	8660	83.91	12.55	27268	18.77	85.14	2449
2.17 - Sink	16.09	88.17	1415	100.00	24.72	23108	16.09	88.17	1415

Table A4 - Size analysis of Bryan Mountain coal (200 mm x 0) after wet attrition

Screen Fractions (mm)	Individual Data			Cumulative Data		
	Mass%	Ash%	kJ/kg	Mass%	Ash%	kJ/kg
Plus - 100.000	4.77	39.55	18036	4.77	39.55	18036
100.000 - 50.000	13.39	37.33	18796	18.16	37.92	18596
50.000 - 25.000	11.64	32.33	20505	29.80	35.74	19342
25.000 - 12.000	12.81	28.21	21916	42.60	33.47	20116
12.000 - 6.000	12.39	27.30	22225	54.99	32.08	20591
6.000 - 3.000	8.40	27.92	22014	63.39	31.53	20779
3.000 - .600	19.67	24.34	23239	83.07	29.83	21362
.600 - .300	1.73	26.69	22434	84.80	29.76	21384
.300 - .150	1.12	35.59	19392	85.92	29.84	21358
.150 - .075	0.92	52.82	13500	86.84	30.08	21275
Minus - .075	13.16	80.18	41[illegible]	100.00	36.68	19020
Total	100.00	36.68	19020			

Mean particle size = 25785 microns

Table A5 - Washing characteristics of Bryan Mountain coal plus 50 mm (200 x 0 mm) after wet attrition (18.16% of total)

Relative Density Fractions	Elementary data			Cumulative data					
				Float			Sink		
	Mass%	Ash%	kJ/kg	Mass%	Ash%	kJ/kg	Mass%	Ash%	kJ/kg
Float- 1.30	0.03	2.18	30815	0.03	2.18	30815	100.00	37.01	18907
1.30 - 1.35	10.24	6.09	29478	10.27	6.08	29482	99.97	37.02	18904
1.35 - 1.40	31.62	10.30	28038	41.89	9.27	28392	89.73	40.55	17697
1.40 - 1.45	8.20	16.49	25922	50.09	10.45	27988	58.11	57.01	12070
1.45 - 1.50	6.37	23.28	23601	56.46	11.90	27493	49.91	63.66	9794
1.50 - 1.55	5.41	29.52	21467	61.87	13.44	26966	43.54	69.57	7774
1.55 - 1.60	3.07	33.79	20007	64.94	14.40	26637	38.13	75.25	5831
1.60 - 1.70	2.73	41.63	17327	67.67	15.50	26261	35.06	78.88	4590
1.70 - 1.80	2.42	49.40	14670	70.09	16.67	25861	32.33	82.03	3514
1.80 - 1.90	5.11	61.95	10379	75.20	19.75	24809	29.91	84.67	2611
1.90 - Sink	24.80	89.35	1011	100.00	37.01	18907	24.80	89.35	1011

Table A6 - Washing characteristics of Bryan Mountain coal 50 x 6 mm after wet attrition (36.84% of total)

Relative Density Fractions	Elementary data			Cumulative data					
				Float			Sink		
	Mass%	Ash%	kJ/kg	Mass%	Ash%	kJ/kg	Mass%	Ash%	kJ/kg
Float- 1.30	0.63	2.94	30555	0.63	2.94	30555	100.00	28.88	21687
1.30 - 1.35	28.22	5.54	29666	28.85	5.48	29685	99.37	29.04	21631
1.35 - 1.40	22.44	11.58	27601	51.29	8.15	28773	71.15	38.36	18444
1.40 - 1.45	8.32	17.14	25700	59.61	9.41	28344	48.71	50.70	14226
1.45 - 1.50	7.68	22.93	23720	67.29	10.95	27817	40.39	57.61	11862
1.50 - 1.55	3.30	28.84	21700	70.59	11.79	27531	32.71	65.76	9078
1.55 - 1.60	1.48	33.35	20158	72.07	12.23	27379	29.41	69.90	7661
1.60 - 1.70	5.18	40.36	17761	77.25	14.11	26734	27.93	71.84	6999
1.70 - 1.80	2.62	52.97	13450	79.87	15.39	26299	22.75	79.00	4549
1.80 - 1.90	2.66	58.24	11648	82.53	16.77	25826	20.13	82.39	3390
1.90 - Sink	17.47	86.07	2133	100.00	28.88	21687	17.47	86.07	2133

Table A7 - Washing characteristics of Bryan Mountain coal 6 x 0.6 mm after wet attrition (28.07% of total)

Relative Density Fractions	Elementary data			Cumulative data					
				Float			Sink		
	Mass%	Ash%	kJ/kg	Mass%	Ash%	kJ/kg	Mass%	Ash%	kJ/kg
Float- 1.30	4.77	2.67	30647	4.77	2.67	30647	100.00	25.57	22818
1.30 - 1.35	38.70	4.08	30165	43.47	3.93	30218	95.23	26.72	22426
1.35 - 1.40	16.06	10.29	28042	59.53	5.64	29631	56.53	42.21	17127
1.40 - 1.45	6.09	14.98	26438	65.62	6.51	29335	40.47	54.88	12796
1.45 - 1.50	3.93	19.52	24886	69.55	7.24	29083	34.38	61.95	10379
1.50 - 1.55	2.71	23.19	23631	72.26	7.84	28879	30.45	67.42	8507
1.55 - 1.60	1.82	28.02	21980	74.08	8.34	28709	27.74	71.75	7030
1.60 - 1.70	2.77	33.85	19987	76.85	9.26	28395	25.92	74.82	5980
1.70 - 1.80	1.92	45.05	16157	78.77	10.13	28097	23.15	79.72	4304
1.80 - 1.90	1.72	53.86	13145	80.49	11.06	27777	21.23	82.85	3232
1.90 - Sink	19.51	85.41	2358	100.00	25.57	22818	19.51	85.41	2358

Table A8 - Washing characteristics of Bryan Mountain coal 0.6 x 0.3 mm after wet attrition (1.73% of total)

Relative Density Fractions	Elementary data			Cumulative data					
				Float			Sink		
	Mass%	Ash%	kJ/kg	Mass%	Ash%	kJ/kg	Mass%	Ash%	kJ/kg
Float- 1.30	9.82	2.48	30713	9.82	2.48	30713	100.00	26.55	22484
1.30 - 1.35	32.09	3.58	30338	41.91	3.32	30426	90.18	29.17	21588
1.35 - 1.40	9.88	7.93	28848	51.79	4.20	30125	58.09	43.30	16754
1.40 - 1.45	7.14	12.46	27300	58.93	5.20	29783	48.21	50.55	14275
1.45 - 1.50	4.41	15.77	26167	63.34	5.94	29531	41.07	57.18	12011
1.50 - 1.55	3.61	19.00	25064	66.95	6.64	29290	36.66	62.16	10308
1.55 - 1.60	2.75	23.01	23692	69.70	7.29	29069	33.05	66.87	8696
1.60 - 1.70	3.57	31.27	20868	73.27	8.46	28670	30.30	70.85	7335
1.70 - 1.80	2.56	41.06	17522	75.83	9.56	28293	26.73	76.14	5528
1.80 - 1.90	2.11	50.82	14184	77.94	10.67	27911	24.17	79.85	4257
1.90 - Sink	22.06	82.63	3308	100.00	26.55	22484	22.06	82.63	3308

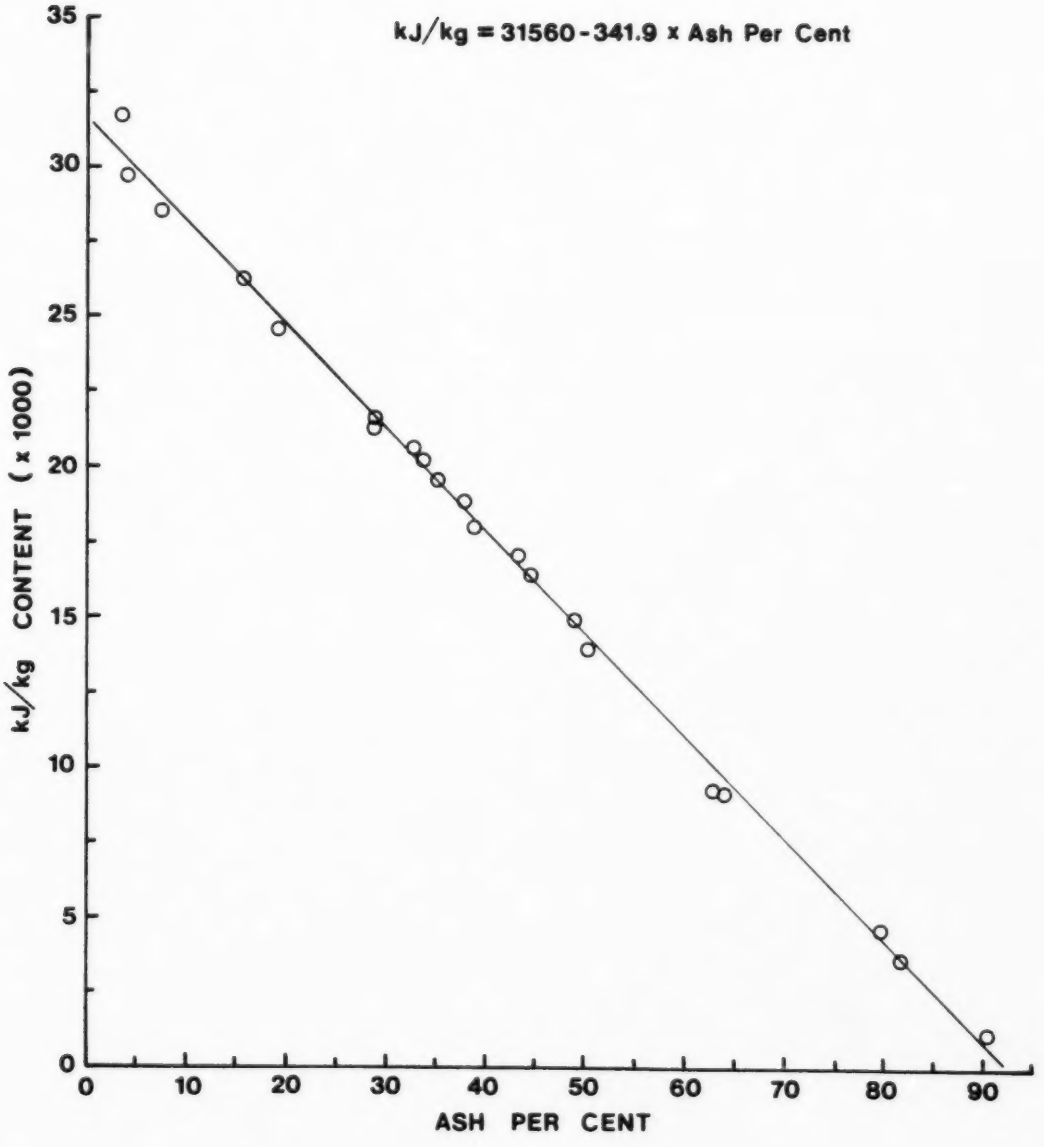

Figure A-1 - Ash-kJ relationship - Bryan Mountain.